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Dynamic brittle fracture as a small horizon limit of unstable nonlocal dynamics

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ABSTRACT

In this discussion, we discuss a new class of models for solving problems of free crack propagation described by the peridynamic formulation. In the peridynamic formulation, material points interact through short-range forces acting over a prescribed horizon. The formulation allows for both continuous and discontinuous deformations associated with cracks. We construct peridynamic models for which the short-range forces between material points are unstable and soften beyond a critical relative displacement. The models can be thought of as representing the dynamics at mesoscopic length scales. Analysis shows that the resulting mesoscopic dynamics is well posed. We upscale the mesoscopic dynamics to identify the macroscopic dynamics as viewed across coarser length scales. Analysis shows that the associated macroscopic evolution has bounded energy given by the bulk and surface energies of classic brittle fracture mechanics. The macroscopic free crack evolution corresponds to the simultaneous evolution of the fracture surface and linear elastic displacement away from the crack set. The elastic moduli, wave speed, and energy release rate for the macroscopic evolution are explicitly determined by moments of the peridynamic potential energy. This provides a necessary connection between nonlocal short-range forces acting over small length scales and dynamic free crack evolution inside a brittle medium as observed at the macroscopic scale. With these observations in hand we can turn this correspondence around and use measured values of elastic moduli and energy release rate to choose peridynamic potentials and influence functions appropriate for a particular material of interest. The calibrated nonlocal model is then used as a tool for numerical simulation.